Second Quarterly Technical Report

Analysis and Evaluation of Technical Data on the Photochromic and Non-Linear Optical Properties of Materials

June 1, 1989

George Mason University

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Contract#: DAAB07-89-C-F404

Project #: CJ829178CJCA

Program Code #: 8E20

Background

The overall goal of this relatively small contractural effort is to provide technical assistance to Dr. Frank Patten (DARPA) in evaluating data on materials, especially polymers, that may be useful in the development of optical limiters for the protection of eyes and electro-optic sensors from exposure to damaging levels of laser radiation. A major task is to assist in the development of a predictative capability in assessing the viability of various protective approaches and to determine the theoretical limitations which may exist in the use of organic materials as optical switches and limiters.

Progress to Date

A search of the literature has been initiated in an attempt to gather into one table the magnitude of the non-linear optical properties of various organic materials as a function of molecular structure. The first quarterly technical report (March 1989) included a partial list of references being reviewed in order to document reported NLO properties of a variety of molecules and systems. Attached as Appendix A to this, the second quarterly report (June 1989) is a table of molecules and sysytems with values reported for their NLO properties; namely, values of chi-3. It is anticipated that this table will represent the starting point for a "living document", continuously updated as new molecules are synthesized and properties measured.

The Principal Investigator attended the Lockheed-Celenese program review held at DARPA headquaters on 26 April. Written comments and suggestions were sent to Dr. Patten following the review.

At no travel expense to this contract, the Principal Investigator attended the "7th DOD Conference on DEW Vulnerabilioty, Survivability and Effects" held in Monterey, CA 9-12 May. Several presentations and poster sessions related to eye and sensor protection or vulnerability to laser radiation. Of special note were the techniques using highly ordered smectic A films developed by Optical Shield, Ltd. and the superheated droplet power limiter reported by Science Applications International Corporation. No new or novel materials with large NLO properties were reported at the conference.

Initial discussions have been held with Mr. Marshal Sparks of BDM Corp. (Los Angeles, CA) and Scientific Research Center, (Playa Del Rey, CA) regarding a possible joint effort to initiate a theoretical study to predict the ultimate limit that may be obtained from an "ideal" NLO polymer or system used as an optical power limiter. These discussions were initiated at the request of Dr. Frank Patten, DARPA. Further discussions and a site visit are scheduled in the near future.

During the next quarter, tabulation of the NLO properties of material will continue and, if agreed to by Dr. Patten, DARPA, and the monitors of this contract, an effort will be initiated to identify the theoretical limitation to the optical switching ability of organic molecules and polymers. This effort would be joint with Mr. Sparks and perhaps others as noted above.

The Principal Investigator is coordinating his activities with the Chemistry Division of the Naval Research Laboratory in Washington, D. C., in order to avoid duplication of effort and to maximize research efficiency.

APPENDIX A

To Accompany Second Quarterly Technical Report

LIST OF MATERIALS EXHIBITING REPORTED NON-LINEAR OPTICAL RESPONSE

This tabulation has been generated in conjunction with Dr.Michael Boyle of the Naval Research Laboratory, Washington, D. C. and will appear as part of a formal NRL Report. Part of this contractural effort at George Mason University was in assisting in the development of that NRL Report and thus this tabulation of data is included here, prior to the distribution of the NRL Report.

LISTING OF χ^3 MATERIALS

THE FOLLOWING LIST OF ORGANIC AND INORGANIC χ^3 MATERIALS IS NOT AN EXHAUSTIVE COMPILATION OF REPORTED RESULTS. RATHER, IT IS AN ATTEMPT TO DEMONSTRATE THE WIDE VARIETY OF MATERIALS THAT HAVE OR ARE BEING EXAMINED AND THE MAGNITUDE OF THEIR RESPECTIVE NONLINEAR OPTICAL EFFECTS.

THE FOLLOWING ABBREVIATIONS ARE USED FOR MATERIAL NAMES:

PMMA	POLY(METHYL METHACRYLATE)
MBBA	N-(-P-METHOXYBENYLIDENE)-P-BUTYLANILINE
PBT	POLY(P-PHEYLENEBENZOBISTHIAZOLE)
4-BCMU	4-BUTOXYCARBONYLMETHYLURETHANE
PTS	POLY(BIS(P-TOLUENE SULFONATE))
DMA-NS	PARADIMETHYLAMINO-B-NITROSTYRENE
DMA-PND	PARADIMETHYLAMINO-L PHENYL,4-NITROBUTADIENE
Pc	PHTHALOCYANINE
MNA	METHYLNITROANILINE
DMSO	DIMETHYLSULFOXIDE
PPV	POLY(P-PHENYLENE VINYLENE)
TCNQ	TETRACYANOQUINODIMETHANE
PDA	POLYDIACETYLENE
PBO	POLY(P-PHENYLENE-2,-6 BENZOBISTHIAZOLE)
PDIAB	
PBI	POLY(BENZIMIDAZOLE)
BBB	POLY[6,9-DIHYDRO-6,9-DIOXOBISBENZIMIDAZO[2,1-B:1',2'-J]BENZO[LMN]PHENANTHROLINE-2,13-DIYL]
BBL	POLY[(7-OXO-7,10-BENZ[DE]IMIDAZO[4',5':5,6]-BENZIMIDAZO[2,1-A]ISOQUINOLONE-3,4:10,11-TETRAYL)-10-CARBONYL]
PQL	POLY[1,6-DIHYDROPYRAZINO[2,3-G]-QUINOXALINE-2,3,8-TRIYL-7(2H)-YLIDENE-7,8-DIMETHYLIDENE)
POL	POLY[2H,11H-BIS[1,4]OXAZINO[3,2-B:3'2'-M]TRIPHENODIOXAZINE-3,12-DIYL-2,11-DIYLIDENE-11,12-BIS(METHYLIDINE)]
PTL	POLY[2H,11H-BIS[1,4]TRIAZINO[3,2-B:3',2'-M]TRIPHENODITHIAZINE-3,12-DIYL-2,11-DIYLIDENE-11,12-BIS(METHYLIDINE)]
DFMP	
BTFP	

THE FOLLOWING ABBREVIATIONS ARE USED IN DESCRIBING THE MATERIAL/MOLECULAR FORM:

TF	THIN FILM
LB	LANGMUIR/BLODGETT FILM
SOLN	SOLUTION
LIQU	LIQUID
MLTN	MOLTEN
LC	LIQUID CRYSTAL
CRYS	CRYSTAL
PLAT	CRYSTAL PLATLETS
MONO	MONOMER
POLY	POLYMER

THE FOLLOWING ABBREVIATIONS ARE USED IN DESCRIBING THE EXPERIMENTAL METHOD FOR DETERMINING THE NONLINEAR OPTICAL EFFECT:

DFWM	DEGENERATE FOUR WAVE MIXING
THG	THIRD HARMONIC GENERATION
RWG	REFLECTION WAVEGUIDE
OKE	OPTICAL KERR EFFECT
EFISH	ELECTRIC FIELD INDUCED SECOND HARMONIC GENERATION
SATIN	SATURATION INTENSITY
SP	SURFACE PLASMON
ETAL	NONLINEAR ETALON EXPERIMENT

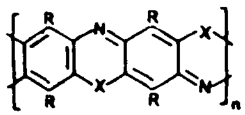
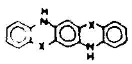
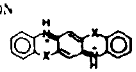
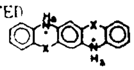
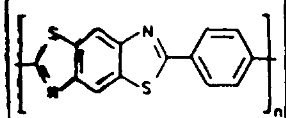
NOTES

(1) IN THE COLUMN DESCRIBING THE MAGNITUDE OF THE X^3 EFFECT, QUANTITIES ENCLOSED IN PARENETHESES ARE MOLECULAR HYPERPOLARIZABILITIES, γ . UNLESS OTHERWISE INDICATED, THE REPORTED VALUE IS AN EXPERIMENTAL MEASUREMENT.

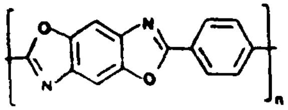
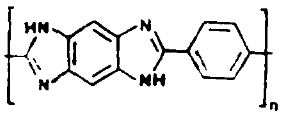
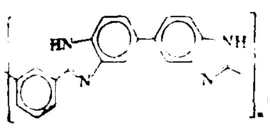
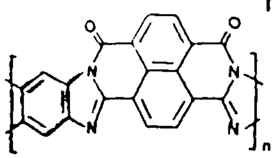
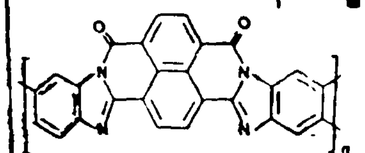
(2) THE COLUMN LABELED TIME REFERS TO THE RESPONSE TIME OF THE NONLINEAR OPTICAL MATERIAL.

(3) DATA OBTAINED FROM NON-REFEREED SOURCES SUCH AS ORAL PRESENTATIONS AND CONFERENCE LECTURE NOTES ARE INDICATED IN THE REFERENCE COLUMN USING A SUPERSCRIPT +.

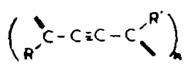
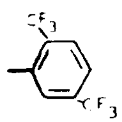
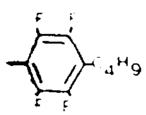
CLASS: BOND ALTERNATION (LADDER AND RIGID ROD)

MOLECULAR MATERIAL			NONLINEAR OPTICAL EFFECT						REFERENCES		
NAME	STRUCTURE	FORM	χ^3 or (γ) (esu)	n_2 (cm²/MW)	λ (μm)	Res/NonRes	TIME	METHOD	AUTHOR	REF#	YEAR
PXL											
PQL	X=NH;R=H										
	R=[CH=CHN(CH$_2$CH$_3$)$_2$];PREPARATION A		3E-10						DALTON‡	80	1988
	R=[CH=CHN(CH$_2$CH$_3$)$_2$];PREPARATION B		2.8E-9						DALTON†	80	1988
		TF	5E-11		0.53	R	ps	DFWM	DALTON	193	1988
	R=[CH=CHN(CH$_2$CH$_2$CH$_3$)$_2$]		2.8E-10						DALTON†	80	1988
	R=[CH=CHNC$_5$H$_{10}$]		1.3E-9						DALTON†	80	1988
		TF	7E-10		0.53	R	ps	DFWM	DALTON	193	1988
	R=[CH=CHNC$_6$H$_{12}$]		1.1E-9						DALTON†	80	1988
PXL	X=CH;PRISTINE 		5E-10						ULRICH‡ DALTON†	37 80	1988 1988
PXL	X=CH;BIPOLARON 		1E-7		CALCULATED				ULRICH† DALTON†	37 80	1988 1988
PXL	X=CH;PROTONATED 		2E-13						ULRICH† DALTON†	37 80	1988 1988
PBT		TF	50-100E-12		1.90	NR		THG	GARITO	10	1986
			9E-12		0.58&0.60	NR	<ps	DFWM	RAO	13	1986
			1E-10						ULRICH‡	37	1988
				5E-7					DOMASH†	187	1988

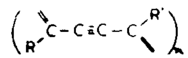
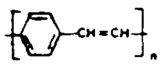
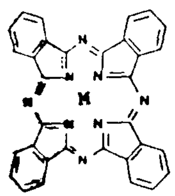
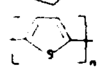
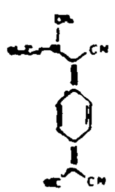
CLASS: BOND ALTERNATING (LADDER AND RIGID ROD)

MOLECULE MATERIAL			NONLINEAR OPTICAL EFFECT						REFFRENCES		
NAME	STRUCTURE	FORM	χ^3 or (γ) (esu)	n_2 (cm^2/MW)	λ (μm)	Res/NonRes	TIME	METHOD	AUTHOR	REF#	YEAR
PBO			2.5E-11		0.63	NR		DFWM	PRASAD†	81	1988
PDIAB											
PBI		TF TF	8E-13 7E-13		1.90 1.90	NR NR		THG THG	GARITO STAMANOFF*	10 96	1986 1988
BBL		TF	2E-9 7E-11		0.53	NEAR R R	ps	DFWM	DALTON† DALTON	80 193	1988 1988
BBB											

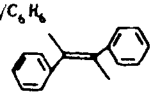
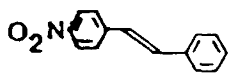
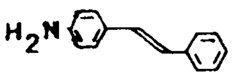
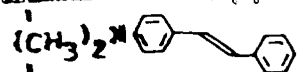
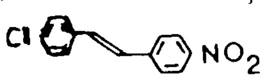
CLASS: LONG CHAIN UNSATURATED

MOLECULE MATERIAL			NONLINEAR OPTICAL EFFECT						REFERENCES		
NAME	STRUCTURE	FORM	χ^3 or (γ) (esu)	n_2 (cm^2/MW)	λ (μm)	Res/NonRes	TIME	METHOD	AUTHOR	REF#	YEAR
POLYDIACETYLENE											
PDA-PTS: $R=R'=CH_2OSO_2C_6H_5CH_3$		TF		3E-6	0.70	NR	1ps	DFWM	CARTER	122	1985
		PLAT	9E-9		0.65	R	<6p	DFWM	CARTER	133	1985
		PLAT	5E-10		0.70	NR	<6ps	DFWM	CARTER	133	1985
		CRYS	1.6E-10	1.8E-6	2.62	NR		THG	SAUTERET	125	1976
		CRYS	8.5E-10		1.89	R		THG	SAUTERET	125	1976
		CRYS	3E-9		1.9	NR		ETAL	HERMANN	180	1980
		TF		1E-6	>0.70	NR	<3ps	RWG	CARTER	136	1984
		TF	1.1E-11		1.94	R			NAKANISHI	131	1988
		COMPOSITE/PMMA	1E-9					DFWM	PRASAD†	82	1988
PDA-TCDU: $R=R'=(CH_2)_4OCONHC_6H_5$		PLAT		1E-6	>0.70	NR		RWG	CARTER	136	1984
		MONO	1.2E-13		1.89	near R		THG	SAUTERET	125	1976
		POLY	7.5E-11		1.89	near R		THG	SAUTERET	125	1976
		POLY	3.7E-11		2.62	NR		THG	SAUTERET	125	1976
PDA-4BCMU: $R=R'=(CH_2)_4OCONHCH_2COOC_4H_9$		TF RED	4E-10	1E-6	0.58&0.61	R(?)	<ps	DFWM	RAO	16	1986
		TF YLW	2.5E-11		0.58&0.61	R(?)	<ps	DFWM	RAO	16	1986
		COMPOSITE/PMMA	3E-10		0.53	R	10ps	OKE	HO	137	1987
		COMPOSITE/PMMA	3E-9		1.06	NR	<ps	OKE	HO	137	1987
POLY-DFBP: R=R'=		(1.09μ) TF	2.4E-11		1.83				NAKANISHI†	131	1988
		(0.98μ) TF	3.7E-11		1.83				NAKANISHI†	131	1988
		(1.09μ) TF	2.6E-11		1.94				NAKANISHI†	131	1988
		(0.98μ) TF	2.4E-11		1.94				NAKANISHI†	131	1988
		(1.09μ) TF	3.5E-11		1.88				NAKANISHI†	131	1988
POLY-BTFP: R=R'=		(0.07μ) TF	2.8E-10		1.83				NAKANISHI†	131	1988
		(0.05μ) TF	2.6E-10		1.83				NAKANISHI†	131	1988
		(0.07μ) TF	1.3E-10		1.94				NAKANISHI†	131	1988
		(0.05μ) TF	1.5E-10		1.94				NAKANISHI†	131	1988
		(0.07μ) TF	3.2E-10		1.88				NAKANISHI†	131	1988

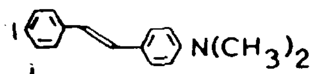
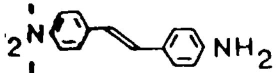
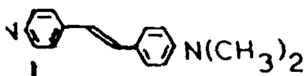
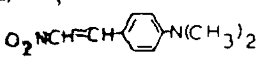
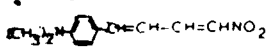
CLASS: LONG CHAIN UNSATURATED

MOLECULAR MATERIAL		NONLINEAR OPTICAL EFFECT							REFERENCES		
NAME	STRUCTURE	FORM	χ^3 or (γ) (esu)	n_2 (cm^2/MW)	λ (μm)	Res/NonRes	TIME	METHOD	AUTHOR	REF#	YEAR
PDA											
	R=$CH_3(CH_2)_{13}$	LB		1E-4	0.67-0.70	R		SP	CARTER	111	1985
	R'=$(CH_2)_8COOH$	LB		1E-6	0.70-1.04	NR		SP	CARTER	111	1985
		CRYS									
	R=$CH_3(CH_2)_{13}$	LB RED	3.4E-11	1E-10	1.064	R		THG	KAJZAR	34	1987
	R'=$(CH_2)_8COOCd$	LB RED	1.5E-10		1.35	R		THG	KAJZAR	34	1987
		LB RED	2.2E-10		1.907	R		THG	KAJZAR	34	1987
		LB BLU	9E-12		1.064	R		THG	KAJZAR	34	1987
		LB BLU	1.9E-11		1.35	R		THG	KAJZAR	34	1987
		LB BLU	3.4E-11		1.907	R		THG	KAJZAR	34	1987
		TRANS	4E-11		1.064	R		THG	KAJZAR	34	1987
		TRANS	1.2E-9		1.35	R		THG	KAJZAR	34	1987
		TRANS	1.3E-9		1.907	R		THG	KAJZAR	34	1987
PPV		TF	1E-10	5E-7	0.60		ps	DFWM	KARASZ‡	188	1988
H_2Pc		LB	3E-9		0.60	R	ps	DFWM	PRASAD	190	1988
NiPc		LB	~1E-9		0.60	R	ps	DFWM	PRASAD	190	1988
CuPc		LB	~1E-9		0.60	R	ps	DFWM	PRASAD	190	1988
Polythiophene		TF&LB	1E-9		0.60	R	ps	DFWM	PRASAD‡	82	1988
TCNQ		LB	5E-12		1.39	R		THG	EGBERT†	189	1988

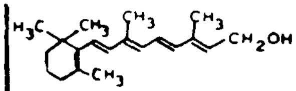
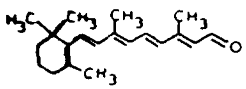
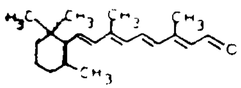
CLASS: LONG CHAIN UNSATURATED

MOLECULE MATERIAL			NONLINEAR OPTICAL EFFECT						REFERENCES		
NAME	STRUCTURE	FORM	χ^3 or (γ) (esu)	n_2 (cm²/MW)	λ (μm)	Res/NonRes	TIME	METHOD	AUTHOR	REF#	YEAR
cis-STILBENE		LIQU	(1.7E-35)		1.06			FWM	OUDAR	75	1977
trans-STILBENE/C_6H_6		SOLN	(4.8E-35)		1.06			FWM	OUDAR	75	1977
4-NITROSTILBENE/C_6H_6		SOLN	(7.5E-34)		1.06			EFISH	OUDAR	75	1977
4-AMINOSTILBENE/C_6H_6		SOLN	(2E-34)		1.06			EFISH	OUDAR	75	1977
4-DIMETHYLAMINOSTILBENE/C_6H_6		SOLN	(4.7E-34)		1.06			EFISH	OUDAR	75	1977
4-CHLOROSTILBENE/C_6H_6		SOLN	(2.7E-35)		1.06			EFISH	OUDAR	75	1977
4-CHLORO-4'-NITROSTILBENE/$CHCl_3$		SOLN	(6.9E-34)		1.06			EFISH	OUDAR	75	1977

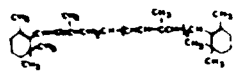
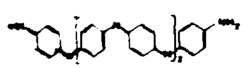
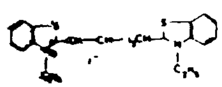
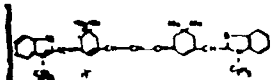
[illegible] CHAIN UNSATURATED

MOLECULE MATERIAL		NONLINEAR OPTICAL EFFECT						REFERENCES		
STRUCTURE	FORM	χ^3 or (γ) (esu)	n_2 (cm^2/MW)	λ (μm)	Res/NonRes	TIME	METHOD	AUTHOR	REF#	YEAR
[illegible]HLORO-4'-DIMETHYLAMINOSTILBENE, $CHCl_3$ 	SOLN	(1E-33)		1.06			EFISH	OUDAR	75	1977
[illegible]ITRO-4'-AMINOSTILBENE/CH_2Cl_2 	SOLN	(9.9E-33)		1.06			EFISH	OUDAR	75	1977
[illegible]ITRO-4'-DIMETHYLAMINOSTILBENE/CH_2Cl_2 	SOLN	(1.7E-32)		1.06			EFISH	OUDAR	75	1977
A-NS/$CHCl_3$ 	SOLN	(8.8E-32)		1.06			EFISH	OUDAR	75	1977
A-PNB/CH_2Cl_2 	SOLN	(2.8E-32)		1.06			EFISH	OUDAR	75	1977
[illegible]MATIC MBBA $CH_3OC_6H_4CHNC_6H_4(CH_2)_3CH_3$	LC	6E-13(z)		1.91			THG	WONG	153	1986
	LC	3E-14(x)		1.91			THG	WONG	153	1986
	LC			0.69		μs	DFWM	FEKETE	159	1980
[illegible]OTROPIC MBBA $CH_3OC_6H_4CHNC_6H_4(CH_2)_3CH_3$	LC	3E-13		1.91			THG	WONG	153	1986

CLASS: LONG CHAIN UNSATURATED

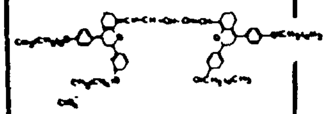
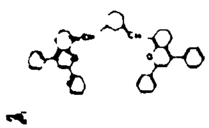
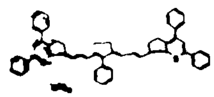
MOLECULE MATERIAL			NONLINEAR OPTICAL EFFECT						REFERENCES		
NAME	STRUCTURE	FORM	χ^3 or (γ) (esu)	n_2 (cm^2/MW)	λ (μm)	Res/NonRes	TIME	METHOD	AUTHOR	REF#	YEAR
RETINOL		MLTN	5.0E-13		1.89			THG	HERMANN	86	1974
			(4.6E-35)		1.89			THG	HERMANN	86	1974
RETINAL		MLTN	1.1E-12		1.89			THG	HERMANN	86	1974
			(9E-35)		1.89			THG	HERMANN	86	1974
trans-RETINAL/DMSO (10E20 molecules/cm^3)		SOLN	(1.3E-34)		1.89			THG	HERMANN	86	1974
cis-trans BIXINE/DMSO (10E20 molecules/cm^3)		SOLN	(3E-34)		1.89			THG	HERMANN	86	1974
DODECAPRENO-BETA-CAROTENE/C_6H_6 (10E18 molecules/cm^3)		SOLN	(1.7E-32)		1.89			THG	HERMANN	86	1974
		SOLN	(4E-33)		2.47			THG	HERMANN	86	1974

CLASS: LONG CHAIN UNSATURATED

MOLECULE MATERIAL			NONLINEAR OPTICAL EFFECT						REFERENCES		
NAME	STRUCTURE	FORM	χ^3 or (γ) (esu)	n_2 (cm^2/MW)	λ (μm)	Res/NonRes	TIME	METHOD	AUTHOR	REF#	YEAR
BETA-CAROTENE											
		GLASS	1E-12	8.1E-8*	1.89	NR		THG	HERMANN	87	1973
(10E19/cm³)	/C_6H_6	SOLN	(1.4E-33)		1.89			THG	HERMANN	86	1974
(10E19/cm³)	/C_6H_6	SOLN	(1.1E-33)		2.47			THG	HERMANN	86	1974
	/ETHANOL	SOLN	1.4E-13**		1.064	R		DFWM	MALONEY	83	1987
	/ETHANOL	SOLN	(7.6E-31)***		1.064	R		DFWM	MALONEY	83	1987
NIGROSINE/WATER		SOLN	1.9E-12**		1.064	R		DFWM	MALONEY	83	1987
			(5.2E-30)***		1.064	R		DFWM	MALONEY	83	1987
											
DTTC/METHANOL		SOLN	5.7E-13**		1.064	R		DFWM	MALONEY	83	1987
			(3.5E-29)***		1.064	R		DFWM	MALONEY	83	1987
											
DMTPC/METHANOL		SOLN	7.3E-13**		1.064	R		DFWM	MALONEY	83	1987
			(2.3E-29)***		1.064	R		DFWM	MALONEY	83	1987
											

*CONVERTED FROM esu TO cm^2/MW USING: 1 esu = 8.1×10^3 cm^2/MW.[127]
**CONVERTED FROM MKS(m^2/V^2) TO esu USING: 10^{-14} esu = 1.4×10^{-22} MKS.[52]
***CONVERTED FROM MKS(m^5/V^2) TO esu USING $\gamma_{esu} = \gamma_{SI} \times 7.16 \times 10^{13}$.[83]

CLASS: LONG CHAIN UNSATURATED

MOLECULE/MATERIAL			NONLINEAR OPTICAL EFFECT						REFERENCES		
NAME	STRUCTURE	FORM	χ^3 or (γ) (esu)	n_2 (cm²/MW)	λ (μm)	Res/NonRes	TIME	METHOD	AUTHOR	REF#	YEAR
A9860/1,2 DICHLOROETHANE		SOLN	1.3E-12*		1.064	R		DFWM	MALONEY	83	1987
			(1.9E-28)**		1.064	R		DFWM	MALONEY	83	1987
											
IR5/1,2 DICHLOROETHANE		SOLN	1.5E-12*		1.064	R		DFWM	MALONEY	83	1987
			(1.4E-28)**		1.064	R		DFWM	MALONEY	83	1987
											
S501/1,2 DICHLOROETHANE		SOLN	8.9E-12*		1.064	R		DFWM	MALONEY	83	1987
			(9.1E-29)**		1.064	R		DFWM	MALONEY	83	1987
											
BUTADIENE			(3.5E-36)		0.69			EFISH	GARITO‡	78	1988
HEXATRIENE (60% trans)			(1.1E-35)		0.69			EFISH	GARITO‡	78	1988
OCTATETRAENE (cis)			(1.8E-36)		0.65			EFISH	GARITO‡	78	1988

*CONVERTED FROM MKS(m^2/V^2) TO esu USING: 10^{-14} esu = 1.4×10^{-22} MKS.[52]

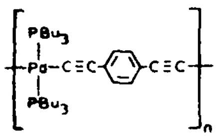
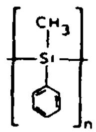
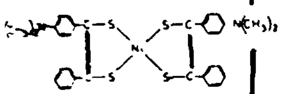
**CONVERTED FROM MKS(m^3/V^2) TO esu USING $\gamma_{esu} = \gamma_{SI} \times 7.16 \times 10^{13}$.[81]

CLASS: LONG CHAIN UNSATURATED

MOLECULE/MATERIAL			NONLINEAR OPTICAL EFFECT						REFERENCES		
NAME	STRUCTURE	FORM	χ^3 or (γ) (esu)	n_2 (cm^2/MW)	λ (μm)	Res/NonRes	TIME	METHOD	AUTHOR	REF#	YEAR
PC6S: A BIPHENYL, SIDE-CHAIN LIQUID CRYSTAL POLYMER; A PROPRIETARY PRODUCT OF HOECHST-CELANESE CORPORATION			2.4E-11*	5.0E-6*	0.53	NR	ns	DFWM	LIPSCOMB	47	1986
			8E-13**	8.4E-7**	0.53	NR	ps	OKE	ALTMAN	116	1988
DVDA LIQUID CRYSTAL			4E-12	8.1E-7***				THG	GARITO	85	1985

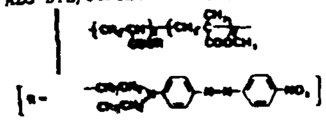
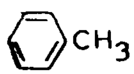
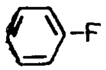
*REPORTED AS 36 x CS_2. OBTAINED THE TABLE VALUE USING A VALUE OF χ^3 = 6.8E-13 esu AMD n_2 = 1.4E-7 cm^2/MW FOR CS_2.[185]
**REPORTED AS 6 x CS_2. OBTAINED THE TABLE VALUE USING A VALUE OF χ^3 = 6.8E-13 esu AND n_2 = 1.4E-7 cm^2/MW FOR CS_2.[185]
***CONVERTED FROM esu TO cm_2/MW USING: 1 esu = 8.1 x 10^3 cm^2/MW.[127]

CLASS: ORGANOMETALLICS

MOLECULE MATERIAL			NONLINEAR OPTICAL EFFECT						REFERENCES		
NAME	STRUCTURE	FORM	χ^3 or (γ) (esu)	n_2 (cm^2/MW)	λ (μm)	Res/NonRes	TIME	METHOD	AUTHOR	REF#	YEAR
PALLADIUN POLY-YNE		TF	3.9E-11*	8.1E-6*	0.53	R		THG	FRAZIER	143	1987
POLYSILANE		TF	1.5E-12 TOO SMALL		1.06 1.91	R NR		THG THG	KAJZAR KAJZAR	145 145	1986 1986
BDN/TOLUENE		SOLN	1.2E-12** (6.2E-29)***		1.064 1.064	R R		DFWM DFWM	MALONEY MALONEY	83 83	1987 1987

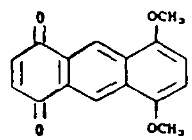
*REPORTED AS 58*$n_2(CS_2)$. OBTAINED USING A VALUE OF χ^3 = 6.8E-13 esu AND n_2 = 1.4E-7 cm^2/MW FOR CS_2.[185]
**CONVERTED FROM MKS(m^2/V^2) TO esu USING: 10^{-14} esu = 1.4×10^{-22} MKS.[52]
***CONVERTED FROM MKS(m^5/V^2) TO esu USING $\gamma_{esu} = \gamma_{SI} \times 7.16 \times 10^{13}$.[83]

CLASS: MISCELLANEOUS

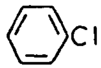
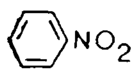
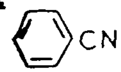
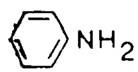
MOLECULE/MATERIAL			NONLINEAR OPTICAL EFFECT						REFERENCES		
NAME	STRUCTURE	FORM	χ^3 or (γ) (esu)	n_2 (cm^2/MW)	λ (μm)	Res/NonRes	TIME	METHOD	AUTHOR	REF#	YEAR
CdS/NAFION (perfluorosulfonic acid ion exchange film); 50 Å CdS particles		TF	NOT GIVEN		0.51	R	10 ns	DFWM	WANG	182	1987
MNA/PMMA:	17% MNA	TF		2.5E-7	1.064			EFISH	GOODWIN	11	1988
	10% MNA	TF	2.3E-12		1.064			THG	KHANARIAN	175	1986
AZO-DYE/COPOLYMER 25.9% DYE		TF	1.3E-12		2.050	NR		THG	MATSUMOTO	147	1987
GOLD COLLOID: 100 Å DIAMETER			1.5E-8		0.527	R	<5ps	DFWM	HACHE	146	1986
SILVER COLLOID: 100 Å DIAMETER			2.4E-9		0.527	R	<5ps	DFWM	HACHE	146	1986
POLYSTYRENE LATEX MICROSPHERES IN WATER (.234 MICRON DIAMETER)		SOLN	6.8E-8*	3.6E-3	0.514	NR		DFWM	SMITH	170	1981
BENZENE		LIQU	1.0E-13		1.9	R		THG	MEREDITH	115	1983
		LIQU	(3.9E-36)		1.9	R		THG	MEREDITH	115	1983
		LIQU	1.2E-13		1.064	R		THG	KAJZAR	34	1987
		LIQU	1.1E-13		1.9	R		THG	KAJZAR	34	1987
TOLUENE		LIQU	9.8E-14		1.9	R		THG	MEREDITH	115	1983
		LIQU	(4.6E-36)		1.9	R		THG	MEREDITH	115	1983
FLUOROBENZENE		LIQU	7.1E-14		1.9	R		THG	MEREDITH	115	1983
		LIQU	(3.6E-36)		1.9	R		THG	MEREDITH	115	1983

*REPORTED [illegible] x CS_2. OBTAINED THE TABLE ENTRY USING $\chi^3 = 6.8 \times 10^{-13}$ esu FOR CS_2.[18]

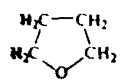
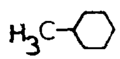
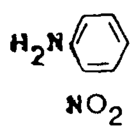
CLASS: MISCELLANEOUS

MOLECULE MATERIAL			NONLINEAR OPTICAL EFFECT						REFERENCES		
NAME	STRUCTURE	FORM	χ^3 or (γ) (esu)	n_2 (cm^2/MW)	λ (μm)	Res/NonRes	TIME	METHOD	AUTHOR	REF#	YEAR
POLYACENE QUINONE in POLY(VINYL CHLORIDE) 10% by weight		TF	1.12E-11		0.53		ps	DFWM	BARBARA	192	1988

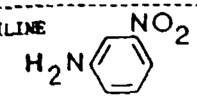
CLASS: MISCELLANEOUS

MOLECULE MATERIAL		NONLINEAR OPTICAL EFFECT							REFERENCES		
NAME	STRUCTURE	FORM	χ^3 or (γ) (esu)	n_2 (cm^2/MW)	λ (μm)	Res/NonRes	TIME	METHOD	AUTHOR	REF#	YEAR
CHLOROBENZENE		LIQU	1.1E-13		1.9	R		THG	MEREDITH	115	1983
		LIQU	(4.3E-36)		1.9	R		THG	MEREDITH	115	1983
BROMOBENZENE		LIQU	1.4E-13		1.9	R		THG	MEREDITH	115	1983
		LIQU	(5.4E-36)		1.9	R		THG	MEREDITH	115	1983
IODOBENZENE		LIQU	2.4E-13		1.9	R		THG	MEREDITH	115	1983
		LIQU	(8.2E-36)		1.9	R		THG	MEREDITH	115	1983
NITROBENZENE		LIQU	1.4E-13		1.9	R		THG	MEREDITH	115	1983
		LIQU	(5.4E-36)		1.9	R		THG	MEREDITH	115	1983
		LIQU	1.7E-13		1.3	R		EFISH	LEVINE	54	1976
		LIQU	(4.3E-35)		1.3	R		EFISH	LEVINE	54	1976
CYANOBENZENE		LIQU	1.0E-13		1.9	R		THG	MEREDITH	115	1983
		LIQU	(4.13E-36)		1.9	R		THG	MEREDITH	115	1983
ANILINE		LIQU	1.7E-13		1.9	R		THG	MEREDITH	115	1983
		LIQU	(5.7E-36)		1.9	R		THG	MEREDITH	115	1983
		LIQU	3.3E-13		1.3	NR		EFISH	LEVINE	54	1976
		LIQU	(7.8E-36)		1.3	NR		EFISH	LEVINE	54	1976
PYRIDINE		LIQU	9.9E-14		1.9	R		THG	MEREDITH	115	1983
		LIQU	(3.4E-36)		1.9	R		THG	MEREDITH	115	1983
ACETONITRILE	CH_3CN	LIQU	2.5E-14		1.9	R		THG	MEREDITH	115	1983
		LIQU	(8.7E-37)		1.9	R		THG	MEREDITH	115	1983

CLASS: MISCELLANEOUS

MOLECULE/MATERIAL			NONLINEAR OPTICAL EFFECT						REFERENCES		
NAME	STRUCTURE	FORM	χ^3 or (γ) (esu)	n_2 (cm^2/MW)	λ (μm)	Res/NonRes	TIME	METHOD	AUTHOR	REF#	YEAR
METHANOL	CH_3OH	LIQU	2.9E-14		1.5	R		THG	MEREDITH	115	1983
		LIQU	(8.0E-37)		1.9	R		THG	MEREDITH	115	1983
ETHANOL	CH_3CH_2OH	LIQU	3.7E-14		1.9	R		THG	MEREDITH	115	1983
		LIQU	(1.3E-36)		1.9	R		THG	MEREDITH	115	1983
2-PROPANOL	$CH_3CH(OH)CH_3$	LIQU	4.1E-14		1.9	R		THG	MEREDITH	115	1983
		LIQU	(1.9E-36)		1.9	R		THG	MEREDITH	115	1983
2-PROPANONE	$CH_3C(O)CH_3$	LIQU	4.4E-14		1.9	R		THG	MEREDITH	115	1983
		LIQU	(2.0E-36)		1.9	R		THG	MEREDITH	115	1983
TETRAHYDROFURAN		LIQU	5.0E-14		1.9	R		THG	MEREDITH	115	1983
		LIQU	(2.2E-36)		1.9	R		THG	MEREDITH	115	1983
METHYL CYCLOHEXANE		LIQU	5.9E-14		1.9	R		THG	MEREDITH	115	1983
		LIQU	(4.6E-36)		1.9	R		THG	MEREDITH	115	1983
CARBON TETRACHLORIDE	CCl_4	LIQU	6.7E-14		1.9	R		THG	MEREDITH	115	1983
		LIQU	(3.1E-36)		1.9	R		THG	MEREDITH	115	1983
CHLOROFORM	$CHCl_3$	LIQU	5.8E-14		1.9	R?		THG	MEREDITH	115	1983
TETRACHLOROETHANE	$C_2H_2Cl_4$	LIQU	8.6E-14		1.9	R?		THG	MEREDITH	115	1983
O-NITROANILINE		LIQU	4.8E-12		1.318	NR?		EFISH	LEVINE	54	1976
		LIQU	(1.2E-34)		1.318	NR?		EFISH	LEVINE	54	1976

CLASS: MISCELLANEOUS

MOLECULE MATERIAL			NONLINEAR OPTICAL EFFECT						REFERENCES		
NAME	STRUCTURE	FORM	χ^3 or (γ) (esu)	n_2 (cm^2/MW)	λ (μm)	Res/NonRes	TIME	METHOD	AUTHOR	REF#	YEAR
M-NITROANILINE		LIQU	3.3E-12		1.318	NR?		EFISH	LEVINE	54	1976
		LIQU	(8.5E-35)		1.318	NR?		EFISH	LEVINE	54	1976
P-NITROANILINE		LIQU	2.0E-11		1.318	NR?		EFISH	LEVINE	54	1976
		LIQU	(5E-34)		1.318	NR?		EFISH	LEVINE	54	1976
ALKANES											
	$CH_3(CH_2)_{n-2}CH_3$	LIQU									
	n=6		4.7E-14		1.064			THG	KAJZAR	52	1987
	n=8		5.0E-14		1.064			THG	KAJZAR	52	1987
	n=10		5.4E-14		1.064			THG	KAJZAR	52	1987
	n=16		6.0E-14		1.064			THG	KAJZAR	52	1987
	$CH_3(CH_2)_{n-2}CH_2Cl$	LIQU									
	n=6		5.6E-14		1.064			THG	KAJZAR	52	1987
	n=10		6.1E-14		1.064			THG	KAJZAR	52	1987
	n=12		6.5E-14		1.064			THG	KAJZAR	52	1987
	n=14		6.7E-14		1.064			THG	KAJZAR	52	1987
	$CH_3(CH_2)_{n-2}CH_2Br$	LIQU									
	n=6		7.5E-14		1.064			THG	KAJZAR	52	1987
	n=10		6.9E-14		1.064			THG	KAJZAR	52	1987
	n=14		6.9E-14		1.064			THG	KAJZAR	52	1987
	$CH_3(CH_2)_{n-2}CH_2I$	LIQU									
	n=6		1.3E-13		1.064			THG	KAJZAR	52	1987
	n=8		1.2E-13		1.064			THG	KAJZAR	52	1987
	n=10		1.0E-13		1.064			THG	KAJZAR	52	1987

CLASS: INORGANICS

MOLECULE MATERIAL			NONLINEAR OPTICAL EFFECT						REFERENCES		
NAME	STRUCTURE	FORM	χ^3 or (γ) (esu)	n_2 (cm^2/MW)	λ (μm)	Res/NonRes	TIME	METHOD	AUTHOR	REF#	YEAR
Pb/Sn FLUOROSPHOSPHATE GLASS WITH											
ACRIDINE ORANGE (8E17 molecules/cm^3)			0.02	0.21	0.514	R	msec	SATIN	TOMPKIN	149	1987
ACRIDINE YELLOW (8E17 molecules/cm^3)			0.06	0.16	0.467	R	msec	SATIN	TOMPKIN	149	1987
BORIC ACID GLASS WITH FLUORESCEIN (10E18 molecules/cm^3)			1		0.467	R	sec	DFWM	KRAMER	148	1986
CdS_xSe_{1-x}	DOPED GLASS		1E-8		0.588	R	ns	DFWM	ROSSIGNOL	30	1987
CRYSTALS											
NaF				7.7E-10*	1.060	NR			NASU	29	1987
NaCl				1.8E-9*	1.060	NR			NASU	29	1987
NaBr				7.8E-9*	1.060	NR			NASU	29	1987
KCl				2.7E-9*	1.060	NR			NASU	29	1987
KBr				1.1E-8*	1.060	NR			NASU	29	1987
CaF_2				2.7E-9*	1.060	NR			NASU	29	1987
CdF_2				1.2E-9*	1.060	NR			NASU	29	1987
CdS				1.9E-7*	1.060	NR			NASU	29	1987
GaAs			0.4	4E-4	0.820				KOWEL	40	1987
			1.2E-11	1.1E-6**	1.3-13	NR			CHANG	110	1981
InSb			1	3E-3 (77K)	5.4				KOWEL	40	1987
			8E-10	6.5E-5**	9-24	NR			CHANG	110	1981
InAs			1.8E-10	1.6E-5**	4-14	NR			CHANG	110	1981
Ge<111>			1.5E-10	1E-5**	2-14	NR			CHANG	110	1981
Si<111>			8.0E-12	7.1E-7**	1.3-7	NR			CHANG	110	1981
HgTe		TF	1.6E-4		10.6				WOLFF	181	1987
[illegible] AND [illegible]/CdTe SUPERLATTICES			-1E-4		10.6		ns	non-DFWM	HOFFMAN	191	1988

*CONVERTED FROM esu TO cm^2/MW USING: 1 esu = 8.1×10^3 cm^2/MW.[127]

**CONVERTED FROM MKS(m^2/V^2) TO cm^2/MW USING: 1 MKS = 7.3×10^{12} cm^2/MW.[127]